



## Manufacturing & Prototyping

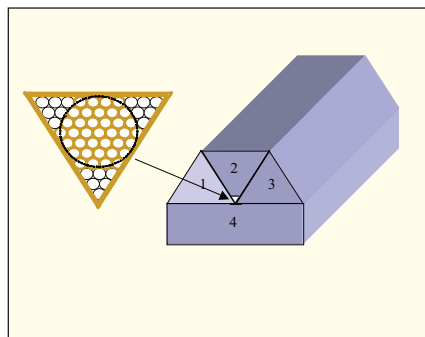
### A Method of Assembling Compact Coherent Fiber-Optic Bundles

The method is based on hexagonal close packing.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of assembling coherent fiber-optic bundles in which all the fibers are packed together as closely as possible is undergoing development. The method is based straightforwardly on the established concept of hexagonal close packing; hence, the development efforts are focused on fixtures and techniques for practical implementation of hexagonal close packing of parallel optical fibers.

The figure depicts salient aspects of one such technique and fixture that may be appropriate for assembling a relatively narrow bundle in which all the fibers are known to be of the same diameter, but the diameter is not known precisely. The positions and ori-



Two of the Three Clamping Blocks are positioned and oriented, relative to the third block, to squeeze the optical fibers into an equilateral triangular cross section. Then the fibers and clamping blocks are fixed in a housing by use of an epoxy.

entations of the three blocks are adjusted to accommodate the diameter and to push the fibers together into an equilateral triangular cross section that enforces the required regular hexagonal arrangement. Once the fibers have been clamped together as shown in the upper part of the figure, the bundle and its clamping blocks could be fixed in the desired position in a housing by use of an epoxy.

*This work was done by Stefan Martin, Duncan Liu, Bruce Martin Levine, Michael Shao, and James Wallace of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

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### Manufacturing Diamond Under Very High Pressure

Pure or doped diamond is crystallized from molten carbon and in solid state.

Marshall Space Flight Center, Alabama

A process for manufacturing bulk diamond has been made practical by the invention of the High Pressure and Temperature Apparatus capable of applying the combination of very high temperature and high pressure needed to melt carbon in a sufficiently large volume. The rate of growth achievable in this process is about ten times the rate achievable in older processes. Depending on the starting material and temperature-and-pressure schedule, this process can be made to yield diamond in any of a variety of scientifically and industrially useful forms, including monocrystalline, polycrystalline, pure, doped, and diamond composite. (Doping makes it possible to impart desired electrical and optical properties, including semiconductivity and color.) The process can also be used to make cubic boron nitride.

The difficulties of manufacturing diamond can be summarized as follows:

- Diamond can be made from dispersed phases of carbon (in which carbon atoms are surrounded by atoms of other ele-

ments or compounds), but the rate of growth is low and the product is impure.

- Diamond crystals can be grown from molten carbon at a high rate, but carbon does not melt at ambient pressure.
- In the range of temperature high enough for forming diamond at a high rate, diamond transforms into graphite if the pressure is not high enough.

The apparatus includes a reaction cell wherein a controlled static pressure as high as 20 GPa and a controlled temperature as high as 5,000 °C can be maintained. A precursor material that consists of either pure or doped diamond powder is placed in a graphite crucible that, in turn, is placed in the reaction cell. The pressure in the cell is increased at ambient temperature, then the temperature is increased. Next, the cell is cooled, at a controlled rate, to a lower temperature where carbon crystallizes. If this controlled cooling is sufficiently slow, single-crystal diamond is formed; faster cooling causes the formation of

polycrystalline diamond. After crystallization, the reaction cell is cooled and depressurized to room temperature and pressure, the reaction cell is extracted from the apparatus, the graphite crucible is extracted from the reaction cell, then the crucible is broken to extract the bulk diamond.

The one major disadvantage of this process is that because of the difficulty of maintaining the combination of high temperature and pressure, the apparatus and process are expensive and the volume of the crucible must be limited. Nevertheless, the process is scalable, and the economic value of the tailored diamond products may justify the cost of scaling the apparatus up to larger production quantities. Working prototype is available at Diamond Materials Inc. facility and can be visited.

*This work was done by Oleg Voronov of Diamond Materials, Inc. for Marshall Space Flight Center. Further information is contained in a TSP (see page 1).*